THE BIOLOGY OF MOLLUSCS

A COLLECTION OF ABSTRACTS
FROM THE
NATIONAL SCIENCE FOUNDATION
GRADUATE RESEARCH TRAINING PROGRAM
JUNE - SEPTEMBER 1968

UNIVERSITY OF HAWAII
HAWAII INSTITUTE OF MARINE BIOLOGY
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INTRODUCTION

by

E. Alison Kay

The following abstracts report the work undertaken by the participants and staff in a graduate research training program, the Biology of Mollusks, conducted at the Coconut Island Laboratory, Hawaii Institute of Marine Biology, from June 18 to September 8, 1968. Supported by a National Science Foundation Grant, the program was under the direction of Dr. Philip Helfrich, Associate Director of the Hawaii Institute of Marine Biology. Four staff members, Dr. Vera Fretter, The University, Reading, England; Dr. E. Alison Kay, University of Hawaii, Honolulu, Hawaii; Dr. Alan J. Kohn, University of Washington, Seattle, Washington; and Dr. Martin J. Wells, Cambridge University, Cambridge, England; 20 graduate students representing 13 institutions in the United States and Canada; and a post-doctoral associate contributed to the program.

Associations of Micro-Mollusks and *Padina* Around Oahu, Hawaii

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Sixteen species were identified among 6,684 specimens of micro-mollusks found on 7200 grams of the brown alga *Padina* spp. along the coastline of Oahu, Hawaii in July and August, 1968. The gastropods *Phasianella variabilis* Pease, *Bittium zebrum* Kiener, an as yet unidentified rissoacean, and the bivalve *Hormomya crebristriatus* Conrad were ubiquitous, occurring on *Padina* from all 12 collecting stations. The density and distribution of the micro-mollusks appear associated with the habit and abundance of the alga, those areas with dense, abundant algae harboring both dense and diverse population of snails.

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Notes on the Ecology of *Drupa morum* 1798 in Hawaii

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The thaisid gastropod *Drupa morum* Roding 1798 occurs in areas of heavy surf from the intertidal zone to depths of 15 m. It preys on polychaetes, mainly *Lysidice collaris*, and less often on other eunicids and members of at least three other families. *L. collaris* is eaten more often than would be expected from its relative abundance in nature. This is the first report of a muricacean preying on polychaetes.

D. morum is most active at night and does not return to a fixed "home". Variation in adult size among populations does not appear to be correlated with population density, wave action, substrate, depth, diet or local distribution.

Homing Behavior in Siphonaria normalis Gould

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Studies on 64 Siphonaria normalis Gould in Hawaii show that animals home to scars that they make on the rocks, moving as the rising and falling tides move past their rocks. Navigation by distant clues (polarized light, sun or moon positions, coastal landmarks, sky brightness) is eliminated as a mechanism involved in homing by a series of experiments in which rocks were rotated while the limpets were off their scars. Dead reckoning navigation and return along previous trails are also eliminated by displacement experiments. Detection of chemical gradients and topographic memory remain as possible mechanism involved in homing.

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Naticid Predation on Dentalium complexum Dall (Dentalidae, Scaphopoda)

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Examination of the profile of the drill hole walls in a shell of Dentalium complexum Dall, collected in 283 fathoms off Maui, Hawaii, reveals sculpture characteristic of holes drilled by gastropods of the family Naticidae. This is the first record of such predation on members of the class Scaphopoda.

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Notes on Feeding and the Functional Morphology of the Gut in the Reef Dwelling Muricid Morula elata Blainville

Peter V. Fankboner

Morula elata Blainville (=Morula spectrum Reeve) feeds on the flesh of corals, particularly the dominant reef-forming Porites compressa Vaughan. Feeding involves "spitting" a saliva on the tissues followed by rasping and sucking on the partially digested flesh. The slender reed-like laterial teeth of the radula are nine times the height of the rachidian. The sweeping and rasping action of this bizarre radula during feeding are described. The buccal cavity and the stomach walls are covered by a thick cuticle, perhaps a protection against nematocysts. Morula elata digests coral tissue and some zooxanthellae, but nematocysts are passed through the gut undischarged. The stomach has features atypical of stenoglossans previously studied. The right duct pouch is pulled deep into the digestive diverticula forming a pseudocaecum. There is also a unique ciliated groove branching off the intestinal groove and functioning as a food re-sorting mechanism.

* * * * * *

Some Preliminary Observations on the Stomachs of Giant Clams (Tridacnidae, Bivalvia)*

Peter V. Fankboner

Examination of the stomach of Hippopus hippopus Linne, Tridacna maxima Roding, and Tridacna squamosa Lamarck reveals an extensive caecum which passes from the stomach and meanders through the digestive gland. This lengthy caecum contains an extension of the main typhlosole and intestinal

*These bivalves are not components of the Hawaiian marine molluskans fauna, but specimens from Eniwetok, Marshall Islands were made available by Mr. Vernon L. Brock, Director, HIMB.

groove. An estimated 200 - 300 ducts pass from the roof of the caecum and the intestinal groove to the tubules of the digestive diverticula. This structure is probably unique among members of the Tridacnidae and may play a significant role in the evolution of gigantism in this family.

* * * * * *

An Experimental Study of the Escape Response of *Strombus maculatus* Sowerby 1842

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The escape response of *Strombus maculatus* and the apparent adaptive morphology of the operculum, foot and eyestalks is described in detail. The response appears to be elicited by a chemical stimulus from two molluscivorous species of *Conus* and two gastropod-eating species of *Cymatium*, but not from other species of these genera. *S. maculatus* habituates within three trials to a solution of "factor" from *Conus pennaceus* but habituates only rarely, and after a long period, to contact with the live cone. The eyes of *S. maculatus* are apparently not used to see the cone; their removal does not drastically disrupt the orientation of the escape response. Tentacle removal appears to interfere with orientation of *S. maculatus* to a surrounding chemical gradient. The escape is shown to be remarkably efficient in the intact *S. maculatus*.

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Notes on Reproduction in Mitra astricta Linn.

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Mitra astricta Linn. produces vase-shaped egg capsules which are attached to the substratum at one end and closed by a plug at the other. Each contains up to 200 eggs which hatch as veliger larvae; there are no nurse eggs. A female deposits 60 - 70 capsules in succession over a period of 17 - 20 hr. Whilst a batch of eggs is passed down the ovarian duct, fertilized, embedded in albumen and surrounded by a capsule wall, the previously formed capsule is moulded in the ventral pedal gland, then manipulated by the anterior edges of the propodium and mesopodium and attached to the substratum. The next capsule is then passed to the gland. Each remains there 15 - 17 min., the time being constant for any one individual. It is moulded to its final form with three flattened sides, and the wall hardened.

The developing veligers rotate in the albuminous fluid which becomes less viscous with the passage of time; some albumen is ingested. A vascular swelling develops on the dorsal surface of the head and, between periods of rotation, the veligers orient themselves with this protruberance against the capsule wall. Towards the end of intracapsular life the protruberance is lost.

* * * * * *

Metamorphosis and the Later Development of the Mantle Cavity of Crucibulum spinosum (Sowerby)

Vera Fretter

The earliest planktonic veliger of Crucibulum spinosum (Sowerby) has a smooth, colorless, symmetrical, planispiral shell of less than one whorl.

This produces the normal coiling of a dextral helicospiral shell. It is complicated by an accompanying growth of the right half of the outer lip which has the effect of gradually altering the axis around which the shell spirals so that a new axis is set up at right angles to the original. Immediately before metamorphosis the columellar edge of the mantle spreads posteriorly over the under surface of the shell, at the periphery of which it secretes an outwardly projecting rim. The rim becomes confluent with the expanded outer lip and together they form the initial part of the limpet-shaped shell.

Throughout larval life the velum is bilobed and has dark brown pigment at the base of the preoral cells. The mesopodium has a triangular sole pointed posteriorly, with anterolateral corners recurved, orange pigment laterally and a median black streak. In the late veliger a pair of semilunar lobes develops on the head, between tentacles and mouth. They will form the lateral lips bordering the mouth of the metamorphosed snail. When the larva becomes benthic and crawls it exhibits the behavior which precedes metamorphosis. The preoral cilia beat vigorously as the velum is extended and faces the substratum: then a violent contraction of the velar muscles draws each lobe toward the head. These movements are repeated several times in succession. If the larva is disturbed it will swim, or contract into the shell and close the opening with the operculum. If not disturbed, there is a last vigorous retraction of the velum muscles and the mouth is opened fully to suck in the velar lobes, one on each side, as their muscles sever attachments to the head leaving no apparent scar. The operculum is cast off and secretion from the pedal glands anchors the snail as the velum disappears. The foot can no longer withdraw into the coils of the shell, but clamps the shell against the substratum for protection of the snail. Ingestion of the velum

takes less than 30 sec. for a vigorous larva. Its tissues fill the oesophagus, stomach and ducts of the digestive gland. Not only are changes affecting the contraction of the columellar muscle coincident with this enormous distension of the gut, but changes in the orientation of the odontophore which bring it into its functional position also occur.

In the recently metamorphosed limpet the columellar muscle originates across the inner lip. Calcareous matter is added to the lip by a pallial fold which forms a flange directed towards the mouth of the shell. This is the anterior part of the cupule characteristic of the shell of the fully grown limpet. The flange is added to as the mantle and consequently the shell spreads anteriorly and to the left of the apex, increasing the size of the mantle cavity which gradually extends along the left side of the foot. Growth in number and length of the ctenidial filaments keeps pace with the growth of the mantle cavity. At the same time the pallial fold forming the cupule circles around the left side of the foot secreting a calcareous wall which gives an area for attachment of the enlarging columellar muscle on one side and an incompressible boundary to the mantle cavity on the other. This encirclement of the foot continues until the cupule is complete.

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Biology of Some Hawaiian Epitoniidae

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Observations during the summer of 1968 on four species of Epitonium in Kaneohe Bay, Oahu, Hawaii, provide additional evidence in support of the idea that these gastropods (Family Epitoniidae) feed exclusively on coelenterates. The species of Epitonium studied, and the coelenterates with which

they were found to be associated, are E. fucatum Pease (with Marcanthea cookei), E. hyalina mokulensis Pilsbry (with Broloceroides lilae), E. ulu Pilsbry (with Fungia scutaria), and a species resembling E. costulatum Sowerby (also with F. scutaria).

E. fucatum maintains at least one highly localized population in Kaneohe Bay and individuals of this population were always found with the large anemone on which they feed. However, individuals of E. fucatum were collected at Kealakekua Bay, Hawaii, not in association with any anemone, although they readily fed on M. cookei and an unidentified anemone in the lab. Two young individuals of E. hyalina were found with the swimming anemone B. lilae, but the snail is rare in the Bay even though the anemone is abundant on parts of the shallow water reefs. E. ulu is the most common species of this genus in Kaneohe Bay, and occurs nearly everywhere the solitary coral on which it feeds occur. Only three individuals of a fourth species, tentatively identified as E. costulatum, were found. These snails were always beneath or close by the solitary coral, F. scutaria, but it could not be determined if the snails were feeding on the coral.

Field growth experiments utilizing E. ulu indicate that growth rate is greatest as the juvenile snail approaches sexual maturity, after which growth rate decreases nearly geometrically. Sexual maturity is reached in perhaps little more than two weeks after the larva has settled out of the plankton.

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Some Aspects of the Functional Anatomy and Biology of *Cymatium* and *Bursa*

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and

Vera Fretter

Species of *Cymatium* and *Bursa* around Oahu, Hawaii, are rock and reef dwellers actively hunting their prey. *Cymatium* eats mollusks. *C. nicobaricum* (Roding), the most voracious, and *C. gemmatum* (Reeve) ate only gastropods in captivity, while *C. pileare* (Linn.) and *C. muricinum* (Roding) ate lamellibranchs. *Bursa cruentata* (Sowerby), *B. granularis* (Roding) and *B. rhodostoma* (Sowerby) fed on polychaetes and sipunculids. The salivary glands are large, their walls muscular, and in species of both genera saliva is expelled from the mouth by the pleurembolic proboscis as the prey is attacked. The fluid is strongly acid and paralyzes the prey. *Cymatium* detaches the soft tissues of mollusks with a pair of strong jaws and the radula. If the prey is a gastropod, it seals the entrance to the shell with mucus while the proboscis works within it. *Bursa* ingests one end of a worm and slowly swallows it whole, and *B. granularis* also surrounds the middle of a polychaete with its lateral lips and doubles it up as it swallows.

The food is accumulated in the initial half of the U-shaped stomach where it is acted on rapidly by muscles and enzymes. The ducts of the digestive gland are concealed in a ventral channel: the anterior one at the end of the posteriorly directed limb, the posterior one near the en-

trance to the short style sac. The entrance is surrounded by a sphincter. The intestine is short with the anus half way along the mantle cavity.

The sexes are separate. The pallial section of the vas deferens, which is open in Cymatium, discharges at the tip of a large, flat penis. Throughout the posterior half of its course along the mantle skirt, its walls are glandular in both genera. The oviduct is closed. Between the albumen and capsule glands are receptacular pouches with ducts communicating with a ventral channel which links with the bursa copulatrix by way of the capsule gland. The bursa is adjacent to the female opening alongside the anus.

The anterior half of the mantle cavity is broad, and the only duct passing through it is the narrow vas deferens. Here the hypobranchial gland is thin, though it is very thick posteriorly. These arrangements allow freedom of movement of the body wall, related to the expulsion of saliva and the action of the proboscis, without affecting the functioning of the mantle cavity.

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Some Common Vermetid Gastropods of Kaneohe Bay, Oahu, and Their Methods of Feeding

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Six commonly occurring vermetids (Mesogastropoda: Vermetidae) have been distinguished in Kaneohe Bay, Oahu, Hawaii. Only one, Dendropoma platypus Morch has previously been recorded in Hawaiian waters; the others, two species of Dendropoma, one species of Serpulorbis, and two

species of Vermetus appear to be undescribed. All are solitary forms, occurring on coral, sea walls, etc.

These vermetids apparently feed by both mucous threads or nets and by ciliary mechanisms. Feeding by mucous threads is initiated when the pedal tentacles are extended and small droplets of mucus are spun off the tips of the tentacles; the mucous droplets become drawn out as fine threads which attach to epiphytic algae and other projections on the substrate. The food-laden threads are retrieved by retraction of the pedal tentacles, moulded on the mesopodial region of the foot, and engulfed by action of the jaws and radula. Feeding by mucous threads appears to be rhythmical, selective, and perhaps stimulated by water currents. Ciliary feeding may occur simultaneously with mucous-thread feeding when mucous boluses formed in the mantle cavity are passed up the right side of the head to the mouth. No correlation between size and development of the gills or type of habitat (i.e., quiet vs. rough water) and either mucous-thread or ciliary feeding was found.

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A Note on Species Abundance, Diversity and Dispersion in Conus Populations in Hawaii

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A sample of 92 individuals from a population of Conus on a fringing reef, censused 12 years after an earlier study, showed 1) the same nine species were present, with the ranks of the two commonest species reversed, but overall rank order of species abundance was not significantly

different; 2) species diversity values ($H = - \Sigma\ p_i\ \ln\ p_i$) were very similar (1.85 and 1.91); 3) fit to the 'broken stick' model of relative abundance was somewhat less close. Ninety-five per cent confidence limits of H at several stations show that H is a reasonably close estimator of population diversity. Individuals in five samples from three mixed-species Conus populations were dispersed randomly.

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Locomotion in Muricacean Gastropods

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Muricacean gastropods were found to move by a unique pedal locomotor wave pattern, a ditaxic diagonal pattern, which has not been included in previous descriptions of gastropod muscular locomotion. The waves move diagonally outward from one end of the foot on the right and left sides of the foot. Of 40 species in 18 families of Hawaiian snails examined, this pattern was found only in the Thaisidae and Muricidae, while little locomotion could be seen in snails of the third muricacean family, the Magilidae. In the Thaisidae the waves move only anterolaterally in Drupa, Thais, Tribulus, Nucella, Nassa, Provexillum and Morula brunneolabrum, and only posterolaterally in six other species of Morula and in Maculotriton. The foot in snails with direct waves is large (sole area greater than 30 mm^2/gram wet weight) and about twice as long as wide, while in snails with retrograde waves it is smaller (less than 25 mm^2/gram) and about three times as long as wide. Species differences were found in rate of passage of waves along the sole, number of simultaneous waves per

side, interval between initiation of waves on the right and left sides of the foot, and size of steps taken. The sequence of events in attachment of the foot to the substrate and initiation of locomotion were the same in all species. In turning, the foot formed one large wave by gradually detaching and reattaching the propodium, followed by the rest of the foot. Reversal of direction at an impasse when shell movement was prevented was accomplished by turning the foot around and resuming normal foot motion while pushing the shell backwards.

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Distribution and Abundance of the Common Vermetids of Checker Reef, Kaneohe Bay, Oahu, Hawaii

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Vermetid gastropods (Mesogastropoda; Vermetidae) are a dominant component of the molluscan fauna of Checker Reef, Kaneohe Bay, Oahu, Hawaii. They occur at the periphery of the reef from the surface to a depth of 6 m, wherever there are hard, silt-free substrates. An unnamed species of Vermetus and three species of Dendropoma were most abundant on substrates covered with the calcareous alga, Porolithon onkodes, with a maximum density of 13,100 vermetids per m^2 observed on the Porolithon ridge. Only the widespread Vermetus was found regularly in and on live portions of Porites compressa and several other species of corals. The relative abundances of the vermetid species differed considerably among the Porolithon ridge, dead coral heads and Porites.

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Observations on the Distribution and Feeding of *Morula uva* (Bolten) and *Morula granulata* (Duclos) (Gastropoda: Thaisidae) in Hawaii

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On Oahu, Hawaii, *Morula granulata* and *M. uva* have sympatric and allopatric populations. Observations on distribution and laboratory experiments suggest that the distribution of *M. granulata* is limited by wave action and enhanced by the ability to prey on many species (listed)--mostly other molluscs. *M. uva*, which occurs in both calm areas and areas with wave action, feeds primarily on members of the family Vermetidae and is limited by their distribution. Where sympatric populations of these two *Morula* occur, each species occupies a different habitat associated with different prey or wave action.

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Preliminary Studies on the Biology and Ecology of *Terebra gouldii* Deshayes

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The toxoglossan gastropod, *Terebra gouldii*, occurs commonly in sand around Ahu O Laka Island, Kaneohe Bay, Hawaii. It is a primary carnivore, preying exclusively on the enteropneust, *Ptychodera flava*, a nonselective deposit feeder. Approximately 30 per cent of the actively crawling population of *T. gouldii* is successful in capturing prey each night, and only one prey specimen is eaten. *T. gouldii* is not found in sand areas where

Ptychodera does not occur. The terebrid is preyed upon by the gastropod, Natica macrochiensis, and the sand crab, Calappa hepatica.

T. gouldii crawls a distance of 1 - 2 m over the sand substrate at night. Locomotion is hindered by hard packed sand and dense algal growth, and the snail is generally absent from these substrate types. T. gouldii is not found in areas of high H_2S content, even though Ptychodera is found there.

T. gouldii spawns groups of egg capsules which are attached to sand grains. There is no planktonic stage. Juveniles hatch through a perforation in the capsule after 34 days, and immediately burrow into the sand.

It is suggested that the distribution and abundance of T. gouldii within sandy areas may be affected by the presence or absence of prey, nature of the substratum, presence and depth below the sand surface of a reducing layer, and presence of a suitable spawning site.

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Oxygen Consumption and Growth of Octopus cyanea

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The availability of octopuses ranging from 0.5 to 2300 gm has made it possible to measure the oxygen consumption of this species through nearly four orders of magnitude. Twenty-five animals were tested using

a temperature-compensated polarographic oxygen probe. As expected, the weight-specific oxygen consumption (cc/gm/hr) falls off linearly with increasing weight, the slope of the regression line being -0.167 on a log-log grid. Animals in the middle range (100 - 200 gm) have a rate of about 0.10 cc/gm/hr. Plotting total oxygen consumption (cc/hr) against weight on the same grid yields a slope of +0.833. Growth rates of animals fed on crabs were similarly faster at small sizes. Several very small octopuses grew from around 0.5 to just over 4 grams in the course of the two months (mid-July to September). Two older animals, in the 1000 - 2000 gm range, doubled their weight in a little more than one month.

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Some Aspects of the Behavior of Aplysia dactylomela (Rang, 1828)

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Under laboratory conditions Aplysia dactylomela was shown to be more active in the daytime than at night, to feed intermittently throughout the day, and, when mature, to copulate in the morning. Observations did not reveal shorter term activity rhythms. Dark-adapted subjects 30 - 40 gms or larger exhibited habituation to turning on a light at one-minute intervals; smaller individuals did not.

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Natural History and Feeding Behavior of *Cratena* sp.cf. *ornata* Baba (Nudibranchiata: Mollusca)

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Cratena sp. cf. *ornata* Baba is a food specialist preying almost exclusively on hydranths of the athecate hydroid, *Pennaria tiarella* McCrady; small aeolids (0.8 cm long) occasionally eat the hydranths of a small hydroid of the family Plumularidae. Eighty per cent of the *Cratena* were found within 1.5 m of *Pennaria* and 15 per cent of these were on the *Pennaria* colonies. The feeding behavior of *Cratena* is described in detail, and it is suggested that the general pattern observed is "typical" of many aeolids that prey on hydroids. *Cratena* eats 2.8 hydranths/hr/cm length of aeolid while the regeneration rate of *Pennaria* hydranths ranges from 0.3 - 1.5 hydranths/hr. The effect of predation by *Cratena* on *Pennaria* is discussed.

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Distance Chemoreception in an Herbivorous Snail, *Trochus sandwichensis*; Its Role in the Avoidance Response to *Conus pennaceus*

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Trochus sandwichensis can detect *Conus pennaceus* at a distance by distance chemoreception, and will rapidly move downstream from the *Conus* in water with a velocity of from 2 to 2/3 m per minute. Removal of the cephalic tentacles, cephalic lappets, neck lobes, epipodial tentacles or

epipodial lappets from the trochid has no effect on its ability to detect the cone nor on its orientation downstream. Oriented response to the chemical stimulus wanes after half an hour.

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Neurophysiology of the Osphradial Ganglion in Trochus sandwichensis (Eydoux and Souleyet, 1852)

Roger Szal

Suction electrodes were used to detect activity in the preganglionic and postganglionic nerves of the osphradial ganglion in two marine prosobranch snails, Trochus sandwichensis and Turbo sandwichensis. No spontaneous activity was detected in any nerves. The preganglionic ctenidial nerve was active when the ctenidium was mechanically stimulated and when acidified sea water (pH 1.7 to 4.0) was applied to the ctenidium. The preganglionic osphradial nerve showed no response when these stimuli were applied to the osphradium. The postganglionic supraesophageal connective was active when: (1) the mantle or dorsal body surface was stimulated either mechanically or with acidified sea water; (2) the ctenidium had acidified sea water applied. The connective was not active when the ctenidium was mechanically stimulated. These results suggest that information from mechanoreceptors in the ctenidium penetrates the central nervous system no further than the osphradial ganglion.

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Larval Heat Tolerance in Crucibulum spinosum (Sowerby)

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Results of heat tolerance experiments with veligers from a Hawaiian population of a widespread Indo-Pacific gastropod, Crucibulum spinosum (Sowerby), support the hypothesis that tropical marine organisms live close to their maximal thermal tolerance. Five days at temperatures 2 - 3° C higher than the maximum ambient cause highly significant differences in mortality rates between experimental and control groups.

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Contribution of Symbiotic Algae to the Oxygen Supply and Survival of Placobranchus ocellatus

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Placobranchus ocellatus van Hasselt, a sacoglossan common in Kaneohe Bay, Oahu, derives respiratory benefit from symbiotic algae lining the inside surface of the parapodia and the dorsum. P. ocellatus sealed into jars and incubated in the sunlight lived 12 - 13 days; dark control lived 4 days. Specimens in the light consistently outlived dark control when oxygen tension was reduced by continuously bubbling nitrogen through the water. In sunlight, approximately three times as much oxygen is produced as is consumed in respiration. The symbionts continued to function for several weeks in the laboratory. Keeping P. ocellatus in total darkness for eight weeks caused them to begin to lose their green color. Freshly-

hatched veligers lack symbionts. P. ocellatus exhibits behavior that would tend to maximize any benefit it may gain from the algae. The activity cycle is light dependent, the animal being strongly photopositive. The animals fluff up their parapodia and gather at the air-water interface or around an air bubbler when exposed to prolonged darkness or low oxygen tensions.

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Studies on Crucibulum spinosum (Sowerby)

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The population of the protandric hermaphrodite, Crucibulum spinosum, in Kaneohe Bay, Oahu, Hawaii occurs on solid substrata swept by a moderate current. The angle of slope of the shell decreases with shelter. Although remaining stationary for some days, young and older individuals move about. Movements in the male are chiefly associated with finding a mate, in the female with spawning. The limpets collect food in suspension and also rasp it from the substratum. At copulation the penis may be passed through the inhalant or exhalant pallial opening of the female. In the former case the male rests on the substratum on the left of the female; in the latter it may be either on the substratum or on the right side of the female's shell.

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Observations on the Shells of Some Fresh-water Neritid Gastropods from Hawaii and Guam

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Observations on the fluviatile neritid prosobranch gastropods, Neritina vespertina Sowerby 1849 and N. granosa Sowerby 1825 from Hawaii, and N. pulligera (Linnaeus 1767) and Septaria porcellana (Linnaeus 1758) from Guam, have yielded a qualitative correlation between clinging ability of the animal and the degree of perfection of the limpet-like (crepidula form) shell. The hypothesis is put forth that the granular ornamentation on the shell of N. granosa and the presence of egg capsules on the shells of many fluviatile neritids (notably N. pulligera and S. porcellana) may create turbulence and minimize the effects of the very strong current in which the animals live.

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Tolerance to Environmental Stresses and Distribution of Nerita picea (Gastropoda: Neritidae)

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Nerita picea is found intertidally on the sea wall adjacent to the Hawaii Institute of Marine Biology, Coconut Island, Kaneohe Bay, Oahu. A study site consisting of two habitats (exposed with no relief from environmental stresses and protected crevices and rubble) had different densities of N. picea. Population densities were much higher on the protected habitat (up to 200/m^2) than the exposed habitat (10/m^2). The

exposed habitat also had Littorina scabra and L. pintado at combined densities of around 100/m^2.

N. picea moves during a tidal cycle. Animals moved vertically down as the tide receded and up as it returned. Movement of between 25 and 50 cm was observed. N. picea moved laterally as well. Lateral movement up to 4 m over a tidal cycle was noted.

N. picea is very resistant to experimental dessication. In a dessication stress approximately equal to the maximum observed under field conditions (36° C and wind velocity around 6.7 m/sec - 15 mph), animals survived up to 16 hr. exposure without fatality. N. picea lost only 8% of the starting body weight in this 16 hr. dessication exposure.

The maximum substrate temperature recorded during the study (June - August 1968) was 37° C. Both N. picea and L. scabra withstood higher temperatures well. At 45° C in saturated humidity, N. picea and L. scabra (which are similar sizes) had a LD_{50} of between 8 and 9 hours. Temperature and dessication, then, do not appear to be limiting N. picea distribution on the exposed habitat. When Littorina was removed from the exposed habitat, N. picea did not show an increase in density in the two weeks following removal, even though recruitment from the protected habitat was possible. Probably Littorina was not excluding N. picea from the exposed habitat.

It is proposed that a functional difference between Littorina and Nerita permits Littorina to exist on the exposed habitats in much greater densities. When exposed to a dessication stress both Littorina and Nerita withdraw the foot into the shell and attach to the substrate by a mucus thread. The mucus thread in Littorina is much stronger than that of Nerita.

N. picea can be dislodged by a slight touch. N. picea is apparently physiologically tolerant of the exposed environment, but not functionally capable of attaching securely to the substrate when the foot is retracted.

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The Food and Habits of Young Post-planktonic Octopus cyanea

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Fifteen small octopuses were collected from the underside of a buoy moored in 35 fathoms off Molokai and given to us by the Director of Sealife Park, Oahu. During the first 36 hours after capture the young animals were inactive, clinging to the glass of their aquaria close to the water surface. On the evening of the second day they became active, descended to the bottom and began a vigorous exploration of the rocks and shells placed below them. Individuals rapidly established 'homes' in cavities in the coral rock and in gastropod shells; from these they would strike out and occasionally emerge to chase off intruders. Twenty-four hours later some of them could be fed upon small fragments of fish and mollusc presented to them in their homes, but they clearly preferred small crabs, which they pursued with vigor and efficiency from the start. Frequent fights made it necessary to isolate the individuals after the first few days. The animals attacked and fed upon a variety of small crustaceans, apparently indiscriminately; they would also, on occasion, eat gastropods and bivalves. In general they refused dead food, such as fish, and were not readily fooled by small inanimate objects, such as lead shot moved about on the end of fine nylon line. Color patterns, including the

'ocellus' and a variety of unilateral and flushing displays, did not differ appreciably from those of adults. The little animals were from the start markedly crepuscular in habit, emerging to sit at the entrance of their homes at dawn and at dusk and mostly hiding during the day. Between July 8 and September 8 the animals grew from about 0.5 to just over 4 grams.

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Sex and Hormones in Octopus cyanea

M. J. Wells and J. Wells

Removal of the optic glands from Octopus cyanea is followed by regression of the testis and a progressive reduction in the number of spermatophores in the testicular ducts. The testis to body weight ratios of 8 animals kept for 39 - 62 days after operation were all below the values obtained from 19 controls of similar size; 5 out of 6 operated animals, kept for 6 - 23 days were below average but within the control range. Spermatophore counts from 9 controls ranged from 133 to 600+, depending on the size (250 - 1500 gr) of the animals concerned. Eight octopuses with the optic glands removed had reduced numbers of spermatophores, those kept the longest (56 and 61 days) having 5 and 0 spermatophores, respectively. Optic gland removal had no effect upon regeneration of the hectocotylus in two animals.

Male O. cyanea have a distinctive sex display, and control animals will display and copulate within minutes when a female is introduced into their aquaria; 31 matings by controls were observed. Following optic gland removal there appears to be no qualitative differences in performance, but the animals display and mate less regularly; 23 pairs were observed,

and 13 of these failed to copulate within 1 hour (cf. only 5 such failures out of 31 tests with controls). On present evidence there is no indication of a progressive decline in sexual behaviour within 2 months of operation.

Octopuses castrated by removal of the testis (or of the testis and its ducts) may copulate (or attempt to copulate) if tested within 36 hours of operation; 3 out of 10 pairs were observed to do so. Thereafter the males lose interest, and no copulations were observed in 8 pairings at 2 - 21 days after castration. A single animal, tested 36 days after removal of the testis and all its ducts, displayed with great vigor and made repeated attempts to insert its hectocotylus. This octopus was found to have greatly enlarged optic glands. In O. cyanea females the optic glands enlarge following extirpation of the subpedunculate lobe from the supra-oesophageal brain (n = 3). This confirms the authors' much more extensive work on the Mediterranean O. vulgaris (J. Exp. Biol. 1959, 36: 1-33), in which the optic glands were shown to be controlled by an inhibitory nerve supply from the subpedunculate lobe. The effect of castration on the state of the gonad-controlling optic glands suggests that there exists a feedback system closely analagous to the testis - hypothalamus -anterior pituitary system of mammals. Further work is in progress on the histological correlates of the behavioral and anatomical effects reported above.

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Some Aspects of the Physiological Factors Affecting the Occurrence of the Marine Pulmonate, Melampus sculptus Pfeiffer

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Melampus sculptus Pfeiffer can tolerate a loss of 80% of its body water. It loses water rapidly when in a dry environment; some individuals measuring larger than 1.0 cm in length have dessicated within 3 1/2 days at a R.H. of approximately 71% and at 74 - 87° C. There is no epiphragm to retard water loss. Individuals differed widely in their tolerance to submersion, from less than 12 hours to more than 120 hours, but half the individuals tested were unable to survive in an aquatic environment for more than 48 hours. Tolerance to 91 °/oo salinity was demonstrated by animals existing on a damp filter paper substratum. Grazing on this substratum stopped when its salinity exceeded 63 °/oo. Salinities as high as 57 °/oo are experienced by individuals living in areas which are infrequently dampened by sea spray. A preference is demonstrated for a substratum dampened with water having a salinity between 26 °/oo and 49 °/oo.

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Aspects of the Behavior of Octopus cyanea Gray

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Seven Octopus cyanea Gray (Mollusca: Cephalopoda) were observed for 120 hours over a period of 60 days in two reef ponds under near natural conditions at Coconut Island, Kaneohe Bay, Oahu, Hawaii. O. cyanea has a crepuscular activity pattern with peaks at 0600 and 1800 local time.

Hunting trips may extend up to 50 meters from the home and may be an hour in duration. O. cyanea will pursue and catch crabs it sees, but its most common method of hunting is speculative--the octopus pouncing on likely areas with the web spread and feeling beneath the web for prey. These leaps are made every 1 to 2 meters along the hunting route. Crabs captured appear to be paralyzed immediately and carried to the home where they are eaten. Several octopuses will use a single hunting ground, and homes may be used by more than one octopus successively. Large octopuses are dominant over smaller ones and will occasionally pursue them when seen. Crab populations were reduced and algal growth was enhanced within the experimental area. O. cyanea is concluded to be a major predator on crabs and an important member of the coral reef community.